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(71) Applicant: **THE BABCOCK & WILCOX COMPANY**
New Orleans, Louisiana 70160-0035 (US)

(72) Inventors:

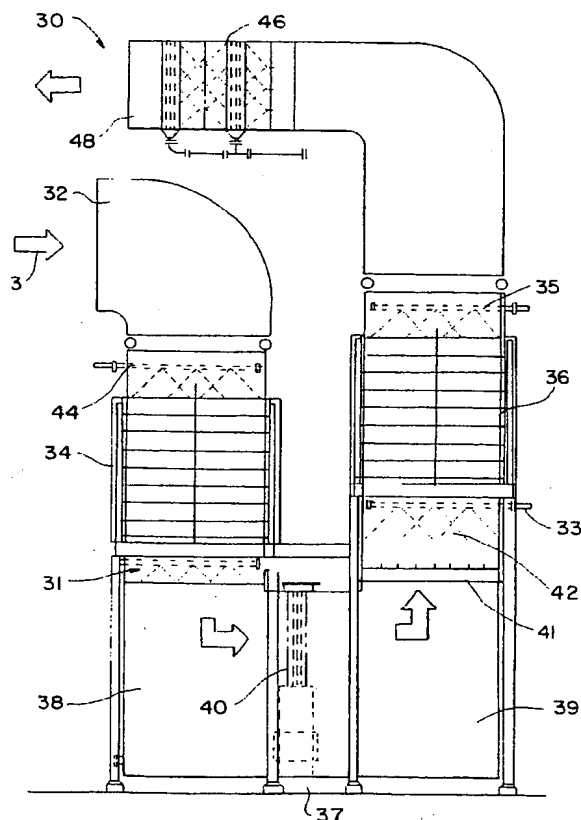
- Johnson, Dennis W.
Barberton, Ohio 44203 (US)
- Schulze, Karl H.
North Canton, Ohio 44721 (US)

(74) Representative: Pilch, Adam John Michael et al
London EC4A 1DA (GB)

(54) Flue gas treatment

(57) A system (30) for treating a flue gas includes a first condensing heat exchanger (34) located in the housing for removing heat from flue gas as the flue gas is passed downwardly therethrough. A first collection tank (38) is located in the housing below the first heat exchanger (34) for collecting liquid and particulate. A second heat exchanger (36) is located in the housing for condensably removing pollutants from the flue gas as the flue gas is passed upwardly through the second heat exchanger (36). A second collection tank (39) is located in the housing below the second heat exchanger (36) for collecting liquid and particulate.

FIG.3



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Description

The present invention relates to the treatment of flue gas.

There are several known systems that are used for the integrated heat recovery and pollutant removal of particulates, sulphur oxides and/or contaminants from a hot combustion exhaust gas in order to comply with US government emissions requirements.

Figure 1 of the accompanying drawings shows one known system which is a condensing heat exchanger unit 2 for recovering both sensible and latent heat from a flue gas 3 in a single unit. The gas 3 passes down through a heat exchanger 4 while water 6 passes upwards in a serpentine path through the heat exchanger tubes. Condensation occurs within the heat exchanger 4 as the gas temperature at the tube surface is brought below the dew point. The condensate falls as a constant rain over the tube array and is removed at the bottom of the unit 2. Gas cleaning can occur within the heat exchanger 4 as the particulates impact the tubes and gas condensation occurs.

The heat exchanger tubes and inside surfaces of the heat exchanger shell 4 are made of, or covered with, a corrosion resistant material such as Teflon (registered trade mark) in order to protect them from corrosion when the flue gas temperature is brought below the acid dew point. Interconnections between the heat exchanger tubes are made outside of the tube sheet and are not exposed to the corrosive flue gas stream 3.

Figure 2 of the accompanying drawings shows a second system which has been proposed, referred to as an integrated flue gas treatment (IFGT) condensing heat exchanger 10 designed to enhance the removal of pollutants from the flue gas stream 3. It is also made of corrosion resistant material or has all of the inside surfaces covered with Teflon.

There are four major sections of the IFGT 10; a first heat exchanger stage 12, an interstage transition region 14, a second heat exchanger stage 16, and a mist eliminator 18. The major differences between the integrated flue gas treatment design 10 and the known condensing heat exchanger design 2 (Figure 1) are:

1. the integrated flue gas treatment design 10 uses two heat exchanger stages 12 and 16 instead of one;
2. the interstage transition region 14, located between the two heat exchanger stages 12 and 16, is used to direct the gas 3 to the second heat exchanger stage 16, acts as a collection tank, and allows for treatment of the gas 3 between the stages 12 and 16;
3. the gas flow 3 in the second heat exchanger stage 16 is upward, rather than downward;
4. the second heat exchanger stage 16 is equipped

with an alkali reagent spray system 20; and

5. the mist eliminator 18 is used to separate the water formed by condensation and entrained from the sprays from the flue gas 3.

Most of the sensible heat and some latent heat is removed from the gas 3 in the first heat exchanger stage 12 of the IFGT 10. The transition region 14 can be equipped with a water or alkali spray system 20. The system 20 saturates the flue gas 3 with moisture before it enters the second heat exchanger stage 16 and also assists in removing sulphur pollutants from the gas 3. The transition section 14 is made of or coated with corrosion resistant material such as a fiberglass-reinforced plastics material. The second heat exchanger stage 16 is operated in the condensing mode, removing latent heat from the gas 3 along with the pollutants. The top of the second heat exchanger stage 16 is equipped with the alkali solution spray system 20. The gas 3 in this stage 16 is flowing upwards while the droplets in the gas 3 fall downwards. This counter-current gas/droplet flow provides a scrubbing mechanism that enhances particulate and pollutant capture. The condensed gases, particulates, and reacted alkali solution are collected at the bottom of the transition section 14. The flue gas outlet of the IFGT 10 is equipped with the mist eliminator 18 in order to reduce the chance of moisture carryover.

According to one aspect of the invention there is provided a system for treating a flue gas, the system comprising:

a housing having an inlet and an outlet, the flue gas entering the housing through the inlet and exiting the housing through the outlet;

first heat exchanger means below the inlet for removing heat from the flue gas, the flue gas passing downwardly in the housing through the first heat exchanger means;

first collection means in the housing below the first heat exchanger means for collecting liquid and particulate;

second heat exchanger means in the housing for condensably removing pollutants from the flue gas, the flue gas passing upwardly in the housing through the second heat exchanger means after passing through the first heat exchanger means;

second collection means in the housing below the second heat exchanger means for collecting liquid and particulate;

mist elimination means in the housing between the first heat exchanger means and the second heat exchanger means for removing mist from the flue gas; and

liquid spray means near the first heat exchanger means and the second heat exchanger means for washing pollutants from the flue gas.

According to another aspect of the invention there is provided a method of treating a flue gas, the method comprising the steps of:

passing the flue gas in a downward direction through first heat exchanger means;

removing heat from the flue gas with the first heat exchanger means as the flue gas is passed through the first heat exchanger means;

passing the flue gas through mist elimination means for removing mist from the flue gas;

passing the flue gas in an upward direction through second heat exchanger means;

condensably removing pollutants from the flue gas with the second heat exchanger means;

washing the flue gas with a liquid near the first heat exchanger means and the second heat exchanger means; and

collecting liquid and particulate beneath the first heat exchanger means and the second heat exchanger means.

Thus, in a preferred embodiment of the invention, the first condensing heat exchanger is located in the housing below the inlet for removing heat from flue gas as the flue gas is passed downwardly in the housing through the first heat exchanger. The second heat exchanger is located in the housing for condensably removing pollutants from the flue gas as the flue gas is passed upwardly through the second heat exchanger. A reagent slurry spray device may also be located in the housing near the second heat exchanger for removing sulphur dioxide (SO_2) from the flue gas.

Accordingly, the preferred embodiment of the present invention provides a segmented system for treating a flue gas which is more efficient than other known systems and methods. Useful heat can be recovered while removing particulates, fly ash, sulphur oxides and/or other contaminants contained in the flue gas formed during the combustion of waste materials, coal and other fossil fuels, which are burned by electric power generating plants, waste-to-energy plants and other industrial processes.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is a schematic view illustrating a known flue gas treatment system;

Figure 2 is a schematic view illustrating an integrated flue gas treatment system; and

Figure 3 is a schematic view illustrating a flue gas treatment system according to an embodiment of the present invention.

A segmented heat exchanger system 30 which is used to treat flue gas 3 using an alkali slurry or solution system 33 is shown in Figure 3. The purpose of this system is to provide improved pollutant removal performance from the flue gas 3 over systems such as the sys-

tem 2 illustrated in Figure 1 and the IFGT system 10 shown in Figure 2.

The system 30 comprises two condensing heat exchanger stages 34 and 36 separated by a transition region 37 for the housing, and having an inlet 32 and an outlet 48. The transition region 37 comprises four sections; a first collection tank 38 beneath the first heat exchanger stage 34, a first mist eliminator 40 between the heat exchangers 34 and 36, a second collection tank 39 beneath the second heat exchanger 36, and a gas/slurry spray device 33. A second mist eliminator 46 is also provided near the outlet 48 in order to reduce the chance of moisture carryover to the exhaust stack. An optional spray 31 is used to promote pollutant removal at the first heat exchanger 34. The heat exchanger tubes and internals of the system 30 are made of corrosion resistant material or are covered with material such as Teflon. The top of the second heat exchanger stage 36 is equipped with an optional spray device 35 that can be used to spray alkali solution in place of the slurry spray system 33, if desired. The spray device 35 can also be used to spray water over the second heat exchanger stage 36 to maintain cleanliness of the heat exchanger and/or enhance particulate removal. An intermittent wash device 44 is provided at the top of heat exchanger 34 in order to wash particulates from the first heat exchanger stage 34 with a washing liquid. The operation of this system 30 is described below.

First, flue gas 3 enters at the top of the first heat exchanger stage 34 from the inlet 32 of the unit 30 and flows downwards through the first heat exchanger 34. The first heat exchanger stage 34 is operated in the condensing mode for removing both sensible and latent heat from the flue gas 3. The droplet formation in the first heat exchanger stage 34 aids in the removal of small particulates and soluble pollutants, such as HF and HCl. The gas 3 then passes through the (optional) spray device 31 before entering the top of the first collection tank 38. When used, spray 31 will generally be a water spray, recirculated from the collection tank 38. However, a reagent may be added to the spray device 31 in order to promote removal of air toxic materials. The spray 31 also assists in the removal of particulates and soluble pollutants from the gas 3 and ensures that the gas 3 is saturated before it enters an (optional) gas/slurry contact region 42. The gas 3 then passes through the first mist eliminator 40 before entering at the top of the second collection tank 39. The condensate collected from the first mist eliminator 40 is drained back into the first collection tank 38.

The flue gas 3 is directed upwards through the (optional) gas/slurry contact region 42 where the sulphur dioxide (SO_2) and other acid gases are removed by the slurry spray device 33. This region 42 consists of the alkali slurry spray 33 combined with gas/slurry contact trays 41 or other high surface area contact mechanisms as appropriate. The alkali slurry 33 interacts with the flue gas 3 so that SO_2 and other acid gases are removed

from the flue gas 3 and the reacted slurry falls downwards and is collected in the second collection tank 39. The flue gas 3 continues travelling upwards through the second heat exchanger stage 36. The second heat exchanger stage 36 can be operated under subcooled conditions in order to improve the removal efficiency of condensable trace elements, such as mercury and other air toxics, and to assist in the removal of any remaining particulate matter. If a soluble reagent, such as a sodium or magnesium based alkali, is used, then the spray device 35 is utilized and operated rather or in addition to the gas/slurry contact region 42.

The tops of the first and second heat exchanger stages 34 and 36 are each equipped with water spray 44 and 35, each of which is activated periodically in order to maintain the cleanliness of the system.

There are several major differences between the present system and the standard IFGT system 10 (Figure 2) which are listed below as follows:

1. The standard IFGT configuration 10 cannot use an alkali slurry to remove SO_2 from the flue gas 3. It must use an alkali solution. The particles in the slurry could erode the Teflon covering on the tubes and cause premature failure of the heat exchanger. In the segmented design of the present system, the slurry 33 does not come into contact with the Teflon covered tubes of the heat exchangers 34 and 36 so there is no danger of damaging them.

2. The transition piece 14 in the standard IFGT design 10 is also used as the collection tank. This single tank 14 collects the condensate and reacted alkali solution from both of the heat exchanger stages 12 and 16. In the segmented design of the present system, however, there are two collection tanks 38 and 39, one below each heat exchanger stage 34 and 36. The collection tanks 38 and 39 are independent of each other. The mist eliminator 40 is also provided between the two collection tanks 38 and 39 in order to ensure that the condensate mist from the first tank 38 does not enter the second tank 39. The size of each tank is determined by the collection and chemistry needs. This isolates the two regions in order to allow optimization of the removal of targeted pollutants in each section or segment and allow the reaction products and pollutants captured in each region to remain segregated for post-treatment as required.

3. In the segmented design of the present system, most of the useable heat is recovered in the first heat exchanger stage 34. The first heat exchanger stage 34 can be operated in the condensing mode. The second heat exchanger stage 36 can be operated under subcooled conditions to enhance trace element removal. In the standard IFGT design 10, both heat exchanger stages 12 and 16 are normally used

to recover useable heat.

The present system provides for an improvement in treating flue gas over the standard IFGT design 10 (Figure 2). The advantages listed below compare the performance of the segmented design of the present system with a comparable standard IFGT design.

The segmented design of the present system has the ability to use either an alkali slurry or an alkali solution. For most applications, the alkali slurry, from a reagent cost standpoint, is more economical than using an alkali solution. The present system offers the user the opportunity to select the most cost effective approach.

For the present system, the first heat exchanger stage 34, the first collection tank 38, and the mist eliminator 40 of the segmented unit 30 pretreat the flue gas 3 to improve the operation of the remaining sections. By operating the first heat exchanger stage 34 in the condensable mode and providing a water spray 31 above the first collection tank 38, the pollutant removal efficiency of the system 30 is improved.

Firstly, more of the particulates will be collected in the pretreatment region in the segmented design of the present system than in the standard IFGT design because of water condensation and spray mechanisms. The addition of the gas/slurry contact region 42 in the segmented unit 30 also improves the overall particulate collection efficiency compared to the standard IFGT design.

Secondly, for the reasons described above, pollutants that are soluble in water, such as HCl and HF, will be removed in the pretreatment region and collected in the first collection tank 38. Since the two collection tanks 38 and 39 are independent of each other, the chlorides and other pollutants and particulates collected in the first collection tank 38 will not contaminate the SO_2 collection system 42 or the second stage heat exchanger 36 pollutant removal process. The chemistry for the SO_2 scrubber system 42 is more stable and continues to operate efficiently longer and with less attention. The standard IFGT design does not have this capability.

Thirdly, the flue gas 3 entering the gas/slurry contact region 42 of the segmented unit 30 under certain conditions will be at a lower temperature than for the standard IFGT design. This improves the SO_2 removal performance of the system 30.

A key advantage is that the present system allows for isolation, and thus optimization, of the two sections or segments 34 and 36. Each segment 34 and 36 is operated at the best conditions for its intended purpose, whether maximizing heat transfer or removal of air toxics. Isolation of the segments 34 and 36 is accommodated through the mist eliminator 40 or other such device.

The present system provides more flexibility and can be optimized more easily than the standard IFGT design. By decoupling the two heat exchanger stages 34 and 36 in the segmented design, the first heat exchanger stage 34 is optimized for heat recovery, while the second heat

exchanger stage 36 can be optimized for pollutant recovery. System optimization is more difficult for the standard IFGT configuration. In the standard IFGT design, both heat exchanger stages 12 and 16 are used for heat recovery and the second stage 16 is also used for pollution removal.

In the present system, the pretreatment of the flue gas is provided by the first heat exchanger 34, first collection tank 38, and the first mist eliminator 40 prevents contaminants such as particulate and chloride from entering the SO₂ removal system 42. For all alkali, organic, or buffering agents used as a SO₂ reagent, such as limestone, lime, amine, magnesium, sodium, etc., pretreatment to remove HCl and HF reduces the reagent requirements and improves the suitability of the products of the SO₂ reactions for regeneration or use as a byproduct. Removal of particulate decreases interference of solid or soluble materials on the downstream process.

Although not shown, the present system may include other features. A third heat exchanger stage could be added downstream of the second stage for the purpose of reheating the gas to improve its buoyancy. Additionally, the heat exchangers 34 and 36 can be made of inert materials such as glass, graphite, alloys or coated or covered with inert materials.

The present system can also be used for achieving H₂S removal. Many reagents can also be used. These include amines, solvents, organics, promoted or buffered reagents, etc., in addition to commonly used reagents such as limestone, sodium alkalis, magnesium alkalis, potassium, amines, magnesium promoted calcium based reagents, and organic acid promoted systems.

Moreover, the second heat exchanger stage 36 of the segmented design 30 can include a refrigeration loop to enhance the removal of heavy metals and other condensable air toxics. If the first two heat exchanger stages are needed to meet heating requirements, a third heat exchanger stage could be added to subcool the flue gas even further. This could be a refrigerant loop.

As mentioned above, the sprays 31, 33 and 35 are optional. Generally, one or two are used. Many combinations are possible. For a combination with the sprays 33 and 35 used for independent control of emissions, it may be possible to separate the zones such that the spray and condensate from the sprays 35 and 36 are captured with a trough or tray to separate this stream from the streams of the spray 33.

Claims

1. A system for treating a flue gas, the system comprising:
 - a housing having an inlet (32) and an outlet (48), the flue gas entering the housing through the inlet (32) and exiting the housing through the outlet (48);
 - first heat exchanger means (34) below the inlet

(32) for removing heat from the flue gas, the flue gas passing downwardly in the housing through the first heat exchanger means (34);

first collection means (38) in the housing below the first heat exchanger means (34) for collecting liquid and particulate;

second heat exchanger means (36) in the housing for condensably removing pollutants from the flue gas, the flue gas passing upwardly in the housing through the second heat exchanger means (36) after passing through the first heat exchanger means (34);

second collection means (39) in the housing below the second heat exchanger means (36) for collecting liquid and particulate;

mist elimination means (40) in the housing between the first heat exchanger means (34) and the second heat exchanger means (36) for removing mist from the flue gas; and

liquid spray means (31,33) near the first heat exchanger means (34) and the second heat exchanger means (36) for washing pollutants from the flue gas.

2. A system according to claim 1, including reagent slurry spray means (33) for spraying the flue gas with a reagent slurry.
3. A system according to claim 2, wherein the reagent slurry spray means (33) is located between the second heat exchanger means (36) and the second collection means (39).
4. A system according to claim 3, including a tray (41) in the housing near the reagent slurry spray means (33).
5. A system according to any one of the preceding claims, wherein the liquid spray means comprises first wash means (44) located above the first heat exchanger means (34).
6. A system according to claim 5, wherein the liquid spray means further comprises water spray means (31) between the first heat exchanger means (34) and the first collection means (38).
7. A system according to claim 5 or claim 6, wherein the liquid spray means further comprises second wash means (35) located above the second heat exchanger means (36).
8. A system according to any one of the preceding claims, including second mist elimination means (46) near the outlet (48) for removing mist from the flue gas.
9. A method of treating a flue gas, the method comprising

ing the steps of:

passing the flue gas in a downward direction
through first heat exchanger means (34);

removing heat from the flue gas with the first
heat exchanger means (34) as the flue gas is passed
through the first heat exchanger means (34);

passing the flue gas through mist elimination
means (40) for removing mist from the flue gas;

passing the flue gas in an upward direction
through second heat exchanger means (36);

condensably removing pollutants from the flue
gas with the second heat exchanger means (36);

washing the flue gas with a liquid near the first
heat exchanger means (34) and the second heat
exchanger means (36); and

collecting liquid and particulate beneath the
first heat exchanger means (34) and the second
heat exchanger means (36).

10. A method according to claim 9, including spraying
the flue gas with a reagent spray.

FIG.1
(PRIOR ART)

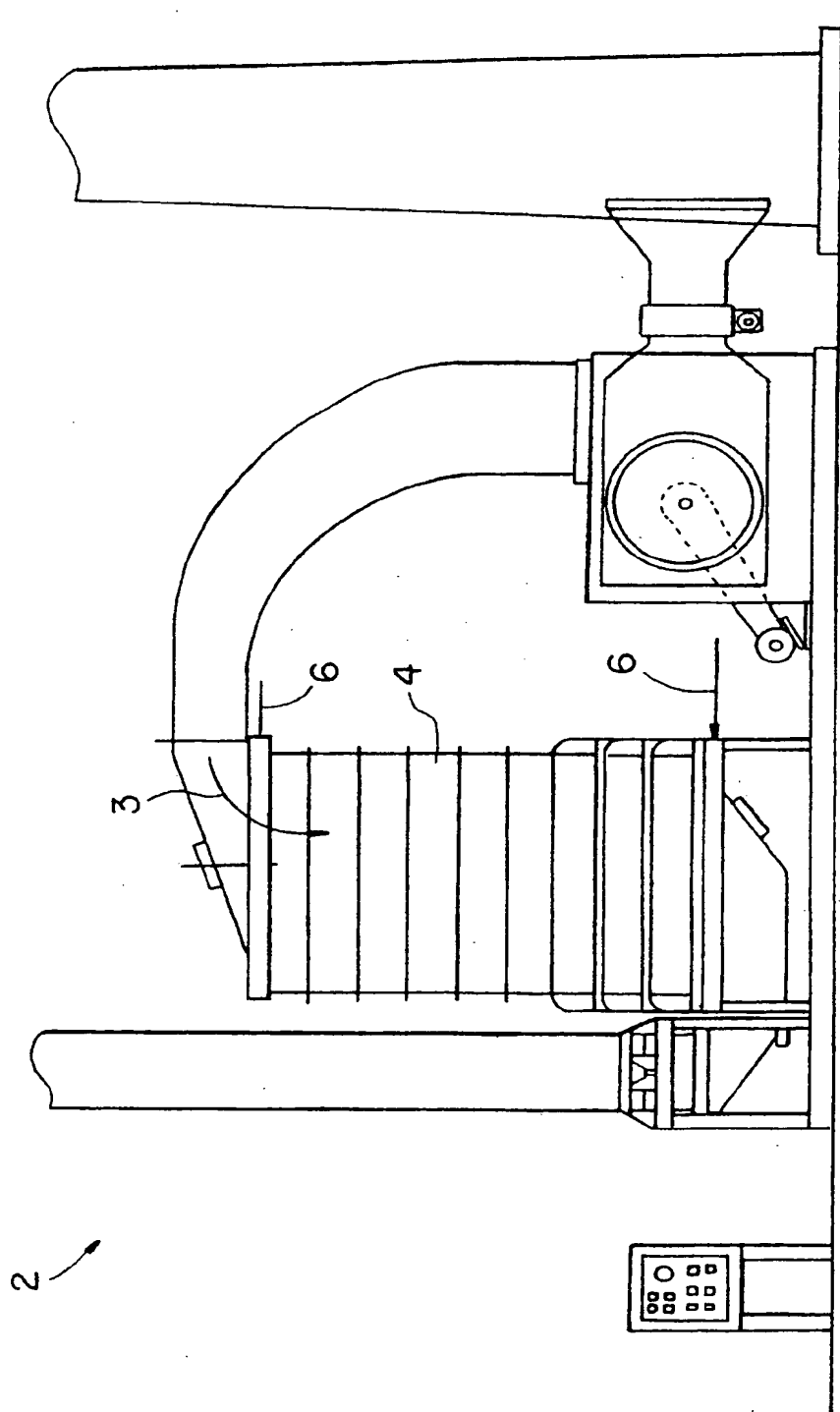


FIG. 2

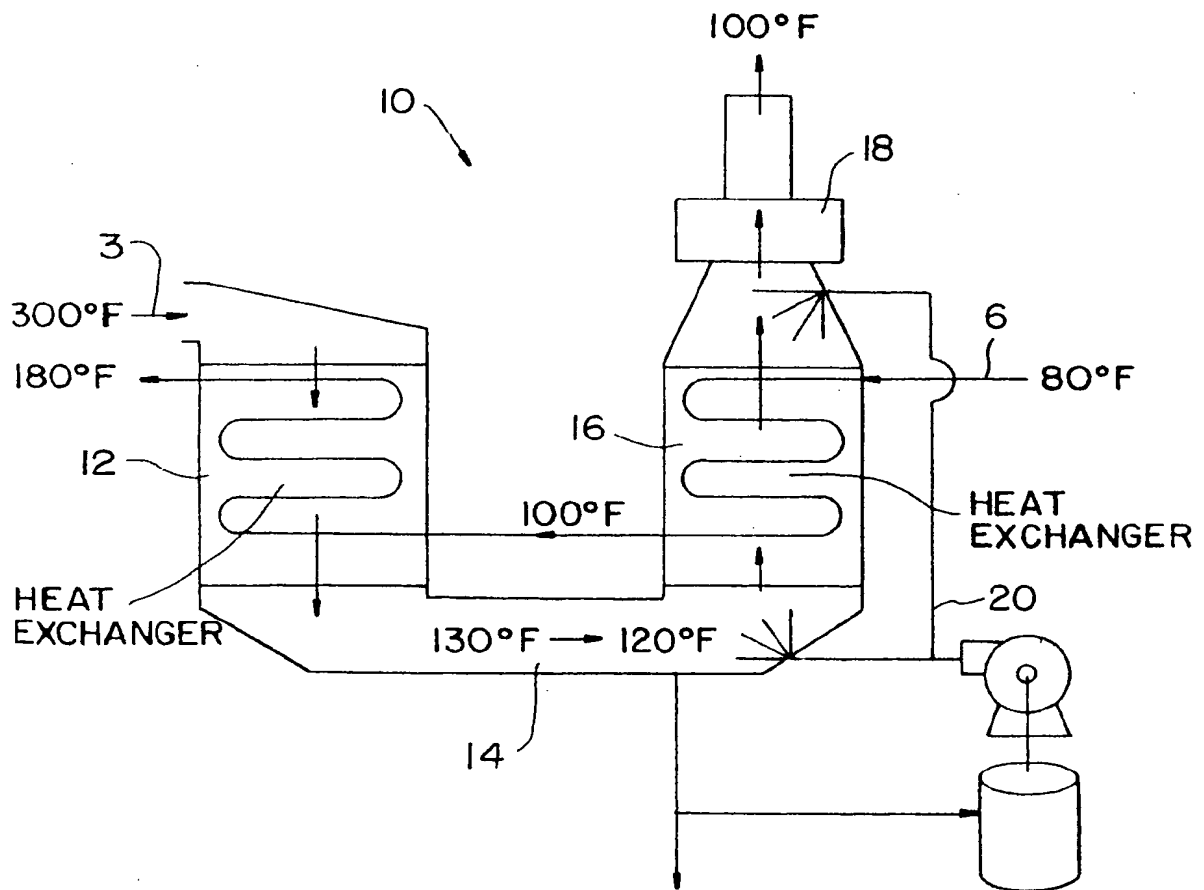


FIG. 3

